# Study on the Diversity and Ecology of *Apis species* in the Semi-arid region of Agra

**Synopsis**

**Submitted in the partial fulfillment for the requirement of**

**Doctor of Philosophy**

**In**

**Zoology**

**Submitted by**

**Paras Kumar Baranwal**

**Under the supervision of**

**Dr. Lalit Mohan**

**Department of Zoology, Faculty of Science**

**Dayalbagh Educational Institute (Deemed to be University)**

**Dayalbagh, Agra- 282005**

**August, 2022**

## Introduction

Bees belongs to the Phylum Arthropoda, class Insecta and the order Hymenoptera (Greek words hymen and pteron are used for membrane and for wing respectively). This Order consisting over 100,000 varied species of bees, ants, wasps and sawflies which have been recognized and to thrive socially in quite large colonies **(Gupta, 2014).** Honey bees of the genus *Apis* are eusocial flying insects. They originated in tropical regions and are native to Asia, Africa and Europe including Japan, Taiwan and the Philippines which are the continental islands **(Seely, 1985).**

**Species diversity** is a combination of two factors: 1. Number of species present i.e., richness per sample and 2. Distribution of individuals among species. An ecosystem cannot function appropriately without species diversity. Species richness which is the number of different species in an ecological community or region has a positive correlation with the density and diversity of links within species interaction webs **(Ebeling *et al.*, 2011).** This in turn stabilizes the different ecosystem services. The decrease in species richness results in a productivity decline in the ecosystem **(Tilman *et al.*, 2001; Cardinale *et al.*, 2006; Duffy *et al.*, 2007).**

The two most widely used species diversity indices are Shannon indices and Simpson indices.

The Shannon index is an information statistic index based on uncertainty, which means it assumes the degree of uncertainty of predicting the sample of all species which are randomly sampled **(Kiernan, 2013).**

The Simpson index is a quantitative measure which represent different types of species present in a community and which can collectively take into account the phylogenetic relations among the individuals spread among as richness, divergence or evenness **(Tucker *et al.*, 2017).**

Honey bees are one of the most crucial agents of pollination in the ecosystem, mainly aiding in cross pollination between plants they forage at and are responsible for pollination in both agricultural as well as wiId plant communities along with the production of honey and other by-products (**Treherne, 1923; Ashfaq, 2006**). All species are capable of interbreeding, hybridizing and quick dispersal (**Khan and Khan, 2018**).

According to the Food and Agriculture Organization of the United Nations (FAO), it is estimated that out of the 100 crop species which provide 90% of the food worldwide, 71% of these are bee-

pollinated. They have specialized organ structures on the Tibia of their hind legs called pollen baskets which aid in pollination. They are also fuzzy and carry an electrostatic charge which help adhere pollen grains to their body **(Kumar *et al.*, 2018).** A fascinating and complex way of life, communication system has also been reported in honey bees of genus *Apis* **(Nieh, 1998; Nieh and Roubik, 1998).**

Several ecological factors, both abiotic and biotic, with and without interacting with each other regulate insect abundance and distribution. The adaptive ability and plasticity of responses which has enabled bees to survive and thrive at extreme physical condition. Out of several abiotic factors, temperature and humidity proved to be as the most limiting factors which determine abundance and distribution of insects **(Savopoulou-Soultani *et al*., 2012).** Most of the biotic factors consisting of birds, wax moths, mites, wasps, ants, bee lice, skunks, hive beetles, bears **(Morhe, 1999)**, leaf cutter bees, cockroaches, robber flies, deaths head moth, preying mantis, dragon flies and spiders **(Thakur and Sharma, 1984)** cause interference and inconvenience and thus they are enemies of honey bees.

Semi-arid areas are characterized by a mean annual precipitation ranging from 200 and 700 mm. In semi-arid areas temperature usually stays below 38°C, during evening temperatures drop to around 10°C. Honeybees reach peak activity from 14 - 32°C, lower or higher to this range they usually decrease their activities and do not leave their hive. **(Gallart *et al*., 2002).** The increase in abundance and activity (e.g. foraging behavior and reproduction) of insects in semi-arid regions is usually associated with climatic variables **(Vasconcellos *et al*, 2010)** which are known to be a good determinant of population behavior **(Janzen, 1973; Wolda, 1988).**

Agra is one of the agro climatic South-western Semi-arid zones of Uttar Pradesh (26°44'N and 27°55'S and 77°26W and 78°32E) and forms a segment of upper Gangetic plains of North India. The climate is extremely periodic due to marked diurnal differences in temperature, high saturation deficit and moderately low rainfall. Mean annual temperature is about 23°C and annual precipitation is 760.4 mm **(Singh and Islam, 2010; Singh, 2014).**

**Purpose of the study**

*"If the bees disappeared off the surface of the globe, then man would have only four years of life left. No more bees, no more pollination, no more plants, no more animals, no more man."*--- **Albert Einstein**

*"The biggest problem is the lack of data on bee species distribution and abundance. This is a worldwide problem with the entomologists. Furthermore, much of the bee fauna undoubtly remains undescribed. If we do not know where bee species live, and how abundant they are, it is almost impossible to measure decline and generate prioritized and meaningful conservation strategies."*--- **Mir *et al*., 2017**

There is no documented information on the species diversity of *Apis* in Semi-Arid habitat. Region of Agra district is one of them. Therefore, proposed study will be undertaken in semi-arid habitat in and around Agra region in order to ascertain extant relationship of climatic condition of semi- arid habitat favorable for beekeeping. There is no record and few anecdotal knowledge about native species of honey bee. Only *Apis mellifera* conservation status is recorded as Data deficient in the IUCN Red list of threatened species **(IUCN, 2020)**

In view of the above, the proposed study will focus to assess the Ecology and Diversity of the genus *Apis* in the semi-arid habitat of Agra region and its sustainable commercial viability.

## Review of Literature

Review of earlier studies is required to let the viewer see what comes before, and to find the gap as to what work accomplished yet and allows researchers to demonstrate understanding and capability of critical evaluation of research in the field. It provides evidence which may be used to support own findings. The earlier reports in the proposed area are mentioned as under.

**Janzen, 1973; Wolda, 1988** studied that the ecosystems characterized by clear distinction between rainy and dry seasons, climatic variables are known to be good determinant of population behavior. **Jakusheva (1983)** observed that mustard secrete much nectar, undergo cross pollination and its flowers, are preferably visited by insects including bees which even don't leave them in drizzling rain. **Powell and Powell (1987)** explained that urbanization, increasing agriculture, deforestation and several geological processes because habitat fragmentation resulting strong negative effect on bees.

**Donovan and Barnes (1996)** explained with his activity "Buzzing a hive" enable an extra ordinary elementary level unit on communication and bee biology integrated with various subjects. **Milner (1996)** explained that in order to compensate to pace for over wintering, honey bees collects large amount of honey, which **Visscher and Dukas (1997**) observed that the same can also be used for economic welfare. **Costanza *et al.* (1997)** explained that bees play very significant role which enable ecosystem service of pollination but their economic value is difficult to quantify to natural ecosystem. **Partarp and Verma (1998)** studied that the annual colony cycle of honeybees in Thailand were migration, swarming, and absconding but in case of *Apis mellifera*, this species over other native species of *Apis* has a prolific queen and undergo swarming and absconding less than native species. Due to this reason beekeepers find *Apis mellifera* has been a popular option for them. **Parmesan *et al.* (1999)** explained that the global climatic change instead of acting independently, interact with each other and cause greater impact on bee population.

**Devillers (2002)** explained role of honey bees, *Apis mellifera* in pollination of plants, trees, in crop productivity and thus in maintaining ecological diversity. **Fell (2005)** explained the essential role of pollinators, according to him pollen grains which is male gametes at the most basic level being transferred to the structure (plant carpel) which contains the ovule / female gamete. **Woods *et al.* (2005)** observed that honeybees are poikilothermic; have partial control over their internal body temperature. Honeybees can maintain lower body temperatures unlike warm-blooded animals, but they can also raise their body temperature through muscular contractions or basking. **Magurran (2004)** explained that it is often troublesome to make complete list of species of insects in a particular area and longer over shorter sampling period is beneficial to find uncommon additional species which is not easy to collect or migrated into the area when sampling started. **Santos *et al*., (2008)** explained the impact of special climate and the prevailing local vegetation of the semi-arid zone of Southwest Bahia differ to a great extent exhibited physico-chemical and chemical characteristics of honey produced greatly discriminated from honey produced in other regions. **Khan and Khan (2018)** reviewed pH of honey commonly lying between 3.2 and 4.5. **Colwell (2009)** quantified effective species diversity using the exponential Shannon's index of entropy in Estimates version 9. **vanEngelsdorp *et al,* 2010;Meixner (2010)** explained importance of healthy environmental

condition, floral wealth for healthy bumper honey production and microorganisms, parasites, diseases detrimental for honey bees and their colonies. **Alaux *et al*. (2010)** explained the importance of poly floral diets for workers as the same increase immune-competence & complete colony tolerance to pathogens. **Rattanawannee *et al.* (2010)** explained that different castes of honey bees such as drones and workers have distinct behavior and flight activities throughout their life span, due to which pattern of their wing venation differs. In order to ascertain whether morphology of the forewing of the same of four native honey bee species was sufficient and reliable to differentiate between their species and sexes within species, they studied to examine thereof.

**Khoury *et al*. (2011)** explained the importance of forager as a limiting factor for sustenance of colony population and according to his model he suggested chronically high forager death rate caused by fast population decline. His model emphasized the role of social feedback mechanisms. In the death rate parameter, his model proposes a bifurcation point such that colony population reaches equilibrium or population declines to zero and the colony fails depend upon above / below a critical threshold. At bifurcation point colony cannot compensate to pace decline of forager bees in the field through the sufficient rate of brood production. **Vanbergen (2013)** explained several pressures interacted with biological processes right from genes to ecosystems threaten health of pollinator and their abundance and diversity. In order to lessen the negative result of ongoing pollinator declines for human health, agricultural production and ecological function, nos. of practical steps supported by interdisciplinary research considered to be necessitated. **Uzunov *et al*. (2014)** studied wide range of behavioral variation exhibited by honey bee colonies which were predominantly depending on environmental factors over their genetic origin. To estimate the effect on expression of Swarming, defensive and hygienic behavior, several factors like year, genotype, origin, location, season were considered and analyzed statistically. For all characters, they observed variability among location which were the sum of all abiotic and biotic components in a given environment had a significant effect more than variability among genotypes on analyzed traits. **EFSA (2014)** explained an integrated environmental risk assessment of multiple stressors on bees. **Couvillon *et al.* (2015)** explained factors which are plant and insect centered. **Xie *et al.* (2016)** explained that plant pollination is benefited with synergistic and complimentary effect caused due to insect flower interaction. **Mir *et al.* (2017)** explained

anthropogenic pressures cause straight impact on community of insect pollinator. **Shuffler (2017)** explained impact of honey bees in world around us as they cause pollination of crops, fruits and vegetables which are one of the reason beekeepers are interested to involve in these activities. **Evans *et al.* (2018)** worked to find relationship between wild bee community metrics (species richness, species diversity, abundance and functional trait diversity) in relation with honey bee metrics (honey production and colony survival) and between land-use types with successful wild bee communities. **Klein *et al.* (2019)** worked on an automated behavior monitoring system to explore the relationship between foraging activity and performance in *Apis mellifera* and recorded several foraging aspects during the lifelong foraging career of individual bees. **Aryal *et al.* (2020)** explained that Ecosystem enables several benefits to mankind in the form of variety of goods and services which comprise of ecosystem processes and their component.

The motive of this comprehensive literature review was to build a strong background of different facets of honey bees thriving in past decades by reviewing different interconnected comprehensive aspects related to honey bees considering their economic importance for the welfare of mankind.

## Objectives

1. To determine honey bee diversity in Semi-arid region of Agra.
2. To determine ecology in relation with honey bee species diversity.
3. To identify and analyze factors affecting honey bee diversity.
4. To identify particular target area having maximum abundance of economically viable species of honey bee.
5. To identify the factors responsible for maintaining honey bee diversity.

## Materials and Methods

### 1 Sampling sites

Selection of target area is based on probability of distinct nesting and foraging sites where honey bees prefer to nest and forage and thus in and around such areas, huge vegetation usually may occurs which consist of varieties of trees, fruits, vegetables, crops and ornamental plants as nesting sites and preferred flora as well and will cover maximum possible areas of a Semi-arid habitat selected for the proposed study.

As the cross pollination by honey bees improves the horticultural crop yields **(Joshi *et al.*, 2021),** increased seed output and quality of vegetables **(Verma and Pratap, 1994)**. Therefore, honey bees are more beneficial to the farmers **(Joshi *et al.*, 2021)** and forests at both local and landscape scale also found to forage in wetland **(Begosh *et al.*, 2020)** and needed as important cause to conserve and upgrade species of bees **(Evans *et al.*, 2018).**

On the basis of the above ground, under mentioned target areas will be visited for sampling as per schedule --

1. Fruit growing areas
2. Crop lands
3. Forests
4. Wetlands

Above target areas were cross verified where honey bees collection was significant in numbers during pilot study.

**2 Methodology**

**2.1 Honey bee diversity**

Honey bee diversity identification is a set of step wise procedure which is consisting of Sample collection and processing, image acquisition and taking measurements, species identification and determination diversity. Data collection will be done by Sweep net method. Protocol of Sampling to species identification will be employed as applicable to above target area in accordance with **Abou-Shara, 2013; Abou-Shara *et al.*, 2013**.

Species diversity which is the product of species richness and species evenness will be determined in terms of Shannon diversity index; which one of the most important index among diversity indices**.**

Random sampling will be deployed because results so obtained in this method should approximate with the obtained results in case of measurement of entire population. Selected sampling sites will be marked with a central stake from which circular transects of radius 35 meter will be formed and GPS co-ordinates will be recorded. Sampling will be done in the circular transect with a targeted sweep net (**Kearns and Oliveras, 2009)** because this method is proved to be the most effective method for collecting native bee assemblages (**Prendergast *et al.*, 2020).** Each honey bee collected will be given an accession no. Field identification and flower species from each sampling sites where bees will be collected (**Kearns and Oliveras, 2009).** Sampling will be done during period of higher abundance of

all floral visitors occurred during morning hours within a standardized time frame of 2 hours (6-8 am.) in accordance with **Kumar *et al.*, 2018.** For honey bee classification, instead of measuring multiple body characteristics by several methods which are time consuming, less accurate & measured by expensive equipment – Geometric morphometric technique **(Santoso *et al,* 2018)** a computer based simple method which correctly identified 99.4 % of tested sample to species **(Bustamante et al., 2021)** and which are fast, more practical, easier, cost-effective and accurate will be employed **(Koca and Kandemir, 2013)**

**2.2 Ecology in relation with honey bee diversity**

It consisting of the assessment of ecological factors like seasonal variation, effect of temperature, relative humidity, rainfall over species richness, diversity index and evenness (**Nirjara *et al,*.2014)**. Effect of biotic (foraging plants, nesting tree) and other abiotic factors like use of pesticides (Types, amount and duration) in fruit growing areas and fields will also be determined.

**2.3 Factors affecting honey bee diversity**

In order to assess factors affecting honey bee diversity in different areas selected, Abiotic factor such as access to water sources, temperature, amount of rainfall and availability of bees fodder and that of anthropogenic factors such as bush fires (deforestation), settlement establishment (Urbanization), farming activities etc. will be conducted in accordance with the method employed by **Nyunza, 2018.**

**2.4 Abundance of economically viable species of honey bee**

Categorized target area having maximum abundance of economically viable species of honey bee under extreme ecological condition encompassing all the seasons will be ascertained on the basis of Shannon index because index value is proportional to diversity **(Makkar and Chhuneja, 2015).**

**2.5 Factors affecting bee diversity**

Identification of such factors in the selected target area will be ascertained on the basis of identification and analysis of factors affecting honey bee diversity. Factors which may cause threats and which may be controlled be communicated to farmers, beekeepers and decision maker to take precautionary measures for effective, sustainable and productive yield of crop, yield of bee products and conservation of environment respectively. Such initiatives would be beneficial to bring about

habitat management programs for sustenance of native pollinators and agricultural expansion **(Makkar and Chhuneja, 2015).**

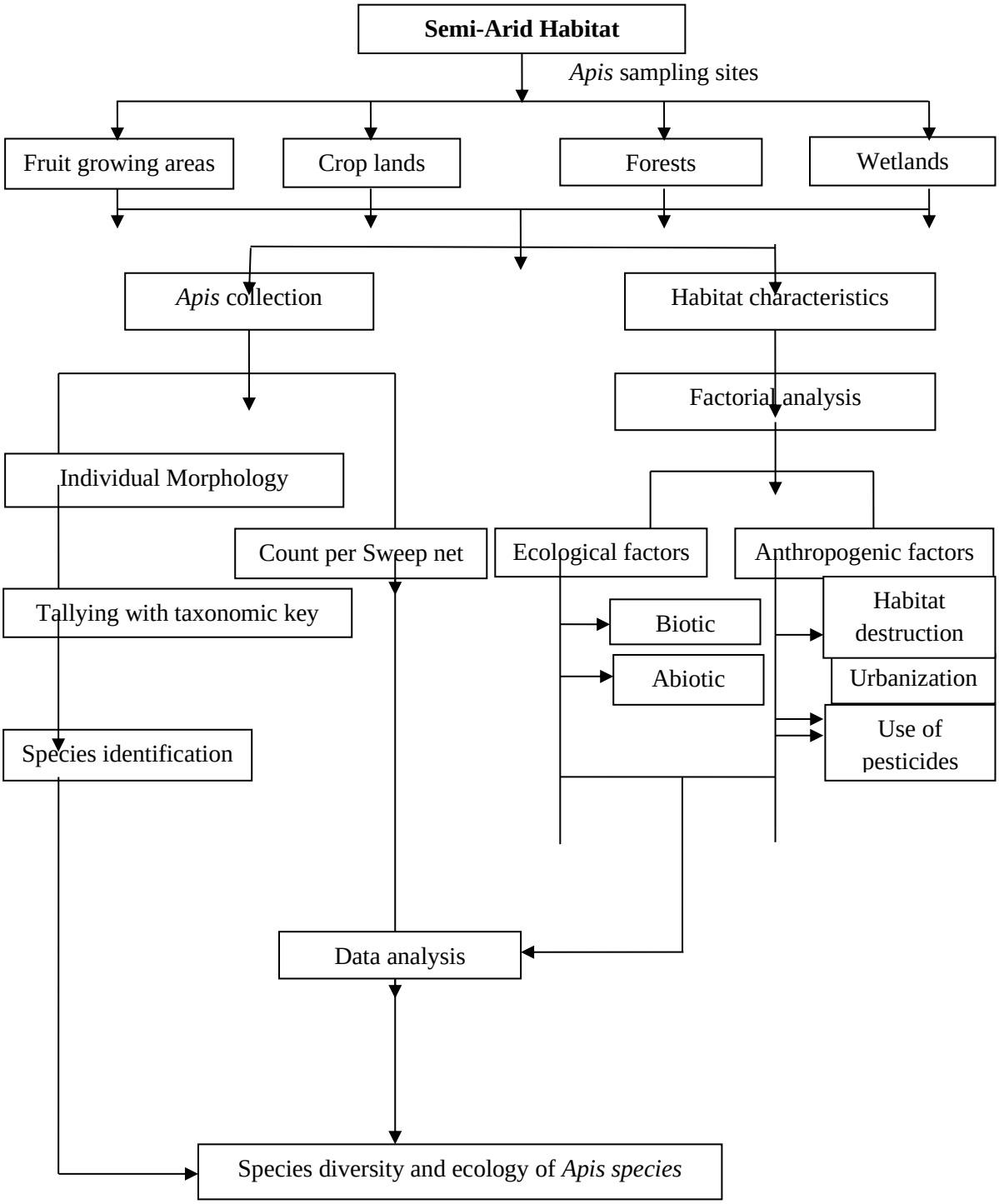
**3 Observations and sampling schedule**

- The observations and sampling schedule of the study will be done thrice a week in Agra region, followed by morphological study by using dissecting microscope.
- Observation and sampling will be done for three consecutive years followed by analysis.

**4 Data collection and analysis**

- Diversity will be determined in terms of Shannon Index. Data will be recorded for individual specific morphological marks / taxonomy and identification key of species, location and hive status will also be recorded viz, thriving hives, abandoned hives and under-construction hives.
- Quantification of data like Shannon index, species diversity and evenness will be expressed as Mean ± S.E. Shannon index and evenness will be expressed as an index which defines the community structure
- Effect of seasonal differences and ecological parameters within assessed parameter will be evaluated (as applicable) in accordance with **Nirjara *et al.*,2014**

## PLAN OF WORK


Semi-Arid Habitat
*Apis* sampling sites
Fruit growing areas
Crop lands
Forests
Wetlands
*Apis* collection
Habitat characteristics
Factorial analysis
Individual Morphology
Count per Sweep net
Ecological factors
Anthropogenic factors
Tallying with taxonomic key
Biotic
Abiotic
Habitat destruction
Urbanization
Use of pesticides
Species identification
Data analysis
Species diversity and ecology of *Apis species*

**References**


Abou-Shaara, H. F. (2013). Wing venation characters of honey bees. *Journal of Apiculture*, *28*(2), 79-86.

Abou-Shaara, H. F., Al-Ghamdi, A. A., & Mohamed, A. A. (2013). Body morphological characteristics of honey bees. *Agricultura*, *10*(1-2), 45-49.

Alaux, C., Ducloz, F., Crauser, D. and Le Conte, Y. (2010). Diet effects on honeybee immunocompetence. *Biology letters*, *6*(4), 562-565.

Aryal, S., Ghosh, S. and Jung, C. (2020).Ecosystem Services of Honey Bees; Regulating, Provisioning and Cultural Functions. *Journal of Apiculture*, 35(2), 119-128.

Ashfaq, M. (2006). Honey Production, Pakistan Agriculture Research Council.

Begosh, A., Smith, L. M., Park, C. N., Mcmurry, S. T., & Lagrange, T. G. (2020). Effects of wetland presence and upland land use on wild hymenopteran and dipteran pollinators in the rainwater basin of Nebraska, USA. *Wetlands*, *40*(5), 1017-1031.

Bustamante, T., Fuchs, S., Grünewald, B., & Ellis, J. D. (2021). A geometric morphometric method and web application for identifying honey bee species (Apis spp.) using only forewings. *Apidologie*, *52*(3), 697-706.

Cardinale, B. J., Srivastava, D. S., Duffy, J. E., Wright, J. P., Downing, A. L., Sankaran, M. and Jouseau, C. (2006). Effects of biodiversity on the functioning of trophic groups and ecosystems. *Nature*, *443*(7114), 989-992.

Colwell, R. (2009). Biodiversity: concepts, patterns, and measurement. The Princeton Guide to Ecology, 257–263.

Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B. and Van Den Belt, M. (1997).The value of the world's ecosystem services and natural capital. *nature*, *387*(6630), 253-260.

Couvillon, M. J., Walter, C. M., Blows, E. M., Czaczkes, T. J., Alton, K. L., and Ratnieks, F. L. (2015). Busy bees: variation in insect flower-visiting rates across multiple plant species. *Psyche*, *2015*.

Devillers, J. (2002).The ecological importance of honey bees and their relevance to ecotoxicology.*Honeybees: estimating the environmental impact of chemicals. Taylor & Francis, London*, 1-11.

Donovan, E. P. and Barnes, E. (1996).A buzzing bee.*Science Activities*, *32*(4), 31-34.

Duffy, J. E., Cardinale, B. J., France, K. E., McIntyre, P. B., Thébault, E., and Loreau, M. (2007). The functional role of biodiversity in ecosystems: incorporating trophic complexity. *Ecology letters*, *10*(6), 522-538.

Ebeling, A., Klein, A. M. and Tscharntke, T. (2011). Plant–flower visitor interaction webs: Temporal stability and pollinator specialization increases along an experimental plant diversity gradient. *Basic and Applied Ecology*, *12*(4), 300-309.

European Food Safety Authority. (2014). Towards an integrated environmental risk assessment of multiple stressors on bees: review of research projects in Europe, knowledge gaps and recommendations. *EFSA Journal*, *12*(3), 3594.

Evans, E., Smart, M., Cariveau, D., &Spivak, M. (2018). Wild, native bees and managed honey bees benefit from similar agricultural land uses. *Agriculture, Ecosystems & Environment*, 268, 162-170.

Fell, R. D. (2005). Mid-Atlantic Orchard Monitoring Guide.*New York: NRAES*, *607*, 255-7654.

Gallart, F., Solé, A., Puigdefábregas, J. and Lázaro, R. (2002).Badland systems in the Mediterranean. *Dryland Rivers: hydrology and geomorphology of semi-arid channels*, 299-326.

Gupta, R. K. (2014). Taxonomy and distribution of different honeybee species.In *Beekeeping for poverty alleviation and livelihood security* (pp. 63-103).Springer, Dordrecht.

IUCN. (2020) The IUCN Red List of Threatened Species. Version 2020-2. (<https://www.iucnredlist.org/species/42463639/42463665#bibliography) (Date accessed 08 December 2020).

Jakusheva, EI Mustard / EI. Jakusheva //Bee breading - №10, 1983.- P.17.

Janzen, D. H. (1973). Sweep samples of tropical foliage insects: effects of seasons, vegetation types, elevation, time of day, and insularity. *Ecology*, *54*(3), 687-708.

Joshi, U., Kothiyal, K., Kumar, Y., & Bhatt, R. (2021). Role of honeybees in horticultural crop productivity enhancement.

Kearns, C. A., & Oliveras, D. M. (2009). Environmental factors affecting bee diversity in urban and remote grassland plots in Boulder, Colorado. *Journal of Insect Conservation*, *13*(6), 655-665.

Khan, N. and Khan, W. (2018). Review of past literature of honey beekeeping and its production in rural area of the world. *Food Science and Quality Management*, *74*, 18-23.

Khoury, D. S., Myerscough, M. R. and Barron, A. B. (2011).A quantitative model of honey bee colony population dynamics.*PloS one*, *6*(4), e18491.

Kiernan, D. (2013).Natural Resources Biometrics. *Open Educational Resources*. 1.https://digitalcommons.humboldt.edu/oer/1

Klein, S., Pasquaretta, C., He, X. J., Perry, C., Sovik, E., Devaud, J. M. and Lihoreau, M. (2019). Honey bees increase their foraging performance and frequency of pollen trips through experience. *Scientific reports*, 9(1), 1-10.

KOCA, A. Ö., & Kandemir, I. (2013). Comparison of two morphometric methods for discriminating honey bee (Apis mellifera L.) populations in Turkey. *Turkish Journal of Zoology*, *37*(2), 205-210.

Kumar, N., Rawat, D. S. and Tiwari, P. (2018). Abundance and visitation rate of apis pollinators on flowers of some multipurpose tree species grown in Muzaffarpur, Bihar, India. *Indian Journal of Scientific Research*, *8*(2), 29-34.

Magurran A. E. (2004). Measuring biological diversity.*Blackwell Publishing, Malden* (USA).

Makkar, G. S., & Chhuneja, P. K. (2015). Diversity assessment of regional crop pollinating bee fauna in ecological perspective. *Eco. Envo. Cons*, *21*, 1811-1816.

Meixner, M. D. (2010). A historical review of managed honey bee populations in Europe and the United States and the factors that may affect them.*Journal of invertebrate pathology*, *103*, S80-S95.

Milner, A. (1996). An introduction to understanding honeybees, their origins, evolution and diversity.*Available via Bibba electronic journal, URL:< http://www. bibba. com*.

Mir, S. A. D. G., Parry, M. A., Yaqob, M., &Nisar, M. (2017).Threats of anthropogenic pressure on insect pollinators. *Vegetos*, *30*, 3.

Morhe RA (ed) (1999) Honey bee pests, predators and diseases. Cornell University Press, Ithaca/New York.

Nieh, J. C. (1998). The role of scent beacon in the communication of food location by thestingless bee, Meliponapanamica.*Behaviour Ecology Sociobiology* 43: 47-58.

Nieh, J. C., and Roubik, D. W. (1998). Potential mechanisms for the communication of height and distance by a stingless bee, Meliponapanamica. *Behaviour Ecology Sociobiology*43: 387-399.

Nirjara, G., Suchitra, S., Sujatha, P., & Geeta, P. (2014). Insect Diversity and its co-relation with Ecological Parameters in and around Wadhwana--a Wetland in Central Gujarat.

Nyunza, G. (2018). Anthropogenic and climatic factors affecting honey production: The case of selected villages in Manyoni District, Tanzania. *Journal of Agricultural Biotechnology and Sustainable Development*, *10*(3), 45-57.

Parmesan, C., Ryrholm, N., Stefanescu, C., Hill, J. K., Thomas, C. D., Descimon, H. and Warren, M. (1999).Poleward shifts in geographical ranges of butterfly species associated with regional warming. *Nature*, *399*(6736), 579-583.

Partap, L. and Verma, L. R. (1998, March). Asian bees and beekeeping: Issues and initiatives. In *Proceeding of fourth Apicultural Association International Conference, Kathmandu, March 23* (Vol. 28, pp. 3-14).

Powell, A. H., and Powell, G. V. (1987). Population dynamics of male euglossine bees in Amazonian forest fragments. *Biotropica*, 176-179.

Prendergast, K. S., Menz, M. H., Dixon, K. W., & Bateman, P. W. (2020). The relative performance of sampling methods for native bees: an empirical test and review of the literature. *Ecosphere*, *11*(5), e03076.

Rattanawannee, A., Chanchao, C. and Wongsiri, S. (2010). Gender and species identification of four native honey bees (Apidae: Apis) in Thailand based on wing morphometic analysis. *Annals of the Entomological Society of America*, *103*(6), 965-970.

Santos, J. S. D., Santos, N. S. D., Santos, M. L. P. D., Santos, S. N. D. and Lacerda, J. J. D. J. (2008). Honey classification from semi-arid, Atlantic and transitional forest zones in Bahia, Brazil. *Journal of the Brazilian Chemical Society*, *19*(3), 502-508.

Santoso, M. A. D., Juliandi, B., & Raffiudin, R. (2018, October). Honey bees species differentiation using geometric morphometric on wing venations. In *IOP Conference Series: Earth and Environmental Science* (Vol. 197, No. 1, p. 012015). IOP Publishing.

Savopoulou-Soultani, M., Papadopoulos, N. T., Milonas, P., & Moyal, P. (2012). Abiotic factors and insect abundance. *Psyche*, *2012*.

Seeley, T. D. (1985). Labour specialization by workers. *Honeybee Ecology.Prinecton: New Jersy*, 31-35.

Shuffler, E. S. (2017).*A Control and Analysis System for Honey Bee Hives* (Doctoral dissertation, Appalachian State University)

Singh, P. (2014). Population and agro climatic zones in India: an analytical analysis. *Procedia-Social and Behavioral Sciences*, *120*, 268-278.

Singh, R. P. and Islam, Z. (2010). Land use planning in western Uttar Pradesh: issues and challenges. *Recent Research in Science and Technology*, *2*(9).

Thakur A. K. and Sharma O. P. (1984) The spider as bee enemy. *Journal of Bombay Natural History Society*, 81:208-211.

Tilman, D., Reich, P. B., Knops, J., Wedin, D., Mielke, T. and Lehman, C. (2001). Diversity and productivity in a long-term grassland experiment. *Science*, *294*(5543), 843-845.

Treherne, R. C. (1923). The Relation of Insects to Vegetable Seed Production. 15th Annual Report Quebec Soc. Prot. Plants. 1923 pp.47-59 pp.

Tucker, C. M., Cadotte, M. W., Carvalho, S. B., Davies, T. J., Ferrier, S., Fritz, S. A. and Mazel, F. (2017). A guide to phylogenetic metrics for conservation, community ecology and macroecology.*Biological Reviews*, *92*(2), 698-715.

Uzunov, A., Costa, C., Panasiuk, B., Meixner, M., Kryger, P., Hatjina, F. and Wilde, J. (2014). Swarming, defensive and hygienic behaviour in honey bee colonies of different genetic origin in a pan-European experiment.*Journal of Apicultural Research*, *53*(2), 248-260

Vanbergen, A. J. and Initiative, T. I. P. (2013). Threats to an ecosystem service: pressures on pollinators. *Frontiers in Ecology and the Environment*, *11*(5), 251-259.

vanEngelsdorp, D., Hayes Jr, J., Underwood, R. M. and Pettis, J. S. (2010). A survey of honey bee colony losses in the United States, fall 2008 to spring 2009. *Journal of apicultural research*, *49*(1), 7-

Vasconcellos, A., Andreazze, R., Almeida, A. M., Araujo, H. F., Oliveira, E. S., & Oliveira, U. (2010). Seasonality of insects in the semi-arid Caatinga of northeastern Brazil. *Revista Brasileira de Entomologia*, *54*, 471-476.

Verma, L. R., & Partap, U. (1994). Foraging behaviour of Apis cerana on cauliflower and cabbage and its impact on seed production. *Journal of Apicultural Research*, *33*(4), 231-236.

Visscher, P. K. and Dukas, R. (1997).Survivorship of foraging honey bees.*Insectessociaux*, *44*(1), 1-5.

Wolda, H. (1988). Insect seasonality: why?. *Annual review of ecology and systematics*, *19*(1), 1-18.

Woods, W. A., Heinrich, B. and Stevenson, R. D. (2005). Honeybee flight metabolic rate: does it depend upon air temperature?. *Journal of Experimental Biology*, *208*(6), 1161-1173.

Xie, Z., Pan, D., Teichroew, J. and An, J. (2016). The potential influence of bumble bee visitation on foraging behaviors and assemblages of honey bees on squash flowers in highland agricultural ecosystems. *PloS one*, *11*(1), e0144590.